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**APPARATUS AND METHOD**  
**FOR AUTOMATED CREATION**  
**OF RESOURCE TYPES**

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**FIELD**

[0001] The present invention relates to techniques for building and managing clustered computer systems. More specifically, the present invention relates to automatic generation of scalable and/or highly available resource types to be installed on multiple nodes of a clustered computer system. The invention also relates to providing a user interface for customizing the generated resource types.

**BACKGROUND**

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a/* [0002] The usage of the Internet has increased dramatically over the last several years. Many popular websites receive millions of "hits" each day. Consequently, the network servers providing content for these websites have experienced a dramatic increase in their workload. In order to process such substantial amounts of network traffic without subjecting clients (surfers) to annoying delays in retrieving web pages, it is advantageous to distribute the applications (or services) handling this traffic among multiple web server hardware nodes, so ~~that the multiple server nodes can operate in parallel to process the network traffic.~~

[0003] A cluster is a collection of coupled computing nodes that provides a single client view of network services or applications, including databases, web services, and file services. In other words, from the client's point of view, a multinode computer cluster operates to provide network services in exactly the same manner as a single server node. Each cluster node is a standalone server that runs its own processes. These processes can communicate with one another to form what looks like (to a network client) a single system that cooperatively provides applications, system resources, and data to users.

[0004] A cluster offers several advantages over traditional single server systems. These advantages include support for highly available and scalable applications, capacity for modular growth, and low entry price compared to traditional hardware fault-tolerant systems.

[0005] A service that spreads an application across multiple nodes to create a single, logical service is called a scalable service. Scalable services leverage the number of nodes and processors in the entire cluster on which they run. One node, called the Global Interface Node or GIF node, receives all application requests and dispatches them to multiple nodes on which the application server is running. If this node fails, the global interface fails over to a surviving node. If any of the nodes on which the application is running fails, the application continues to run on the other nodes with some performance degradation until the failed node returns to the cluster.

[0006] If any of the aforementioned network server nodes fails, it is desirable that other nodes take over the services provided by the failed node such that the entire system remains operational. High Availability (HA) is the ability of a cluster to keep an application up and running, even though a failure has occurred that would normally make a server system unavailable. Therefore, highly available systems provide nearly continuous access to data and applications.

[0007] It is well known in the art that an application, such as a web server, needs to be specially configured to be able to run as a highly-available or scalable application on a computer cluster. Specifically, there must be provided a special program called resource type, that would start an instance of the application, monitor application's execution, detect failure of the application and start another instance of the application if the first instance fails. The term

data service will be used herein to describe a third-party application such as Apache web server that has been configured to run on a cluster rather than on a single server. A data service includes the application software and special additional container process called resource type that starts, stops, and monitors the application.

[0008] One example of the aforementioned resource type is a failover resource type, which is the process by which the cluster automatically relocates an application from a failed primary node to a designated secondary node. Failover services utilize the aforementioned failover resource type. In other words, failover resource type is a container for application instance resources.

[0009] For failover data services, application instances run only on a single node. If the fault monitor detects an error, it either attempts to restart the instance on the same node, or to start the instance on another node (failover), depending on how the data service has been configured. With failover, a clustered computer system provides high availability.

[0010] When a failover occurs, clients might see a brief interruption in service and might need to reconnect after the failover has finished. However, clients are not aware of the physical server from which they are provided the application and data.

[0011] Another example of a data service is a scalable data service. The scalable data service has the potential for running active instances of an application on multiple cluster nodes. Scalable services utilize a scalable resource type to start, stop, and monitor the application. The scalable resource group can be online on multiple nodes, so multiple instances of the service can be running at once.

[0012] Service requests come into the cluster through a single network interface (the

global interface or GIF) and are distributed to the nodes based on one of several predefined algorithms set by the load-balancing policy. The aforementioned load-balancing policy is a set of rules describing how the network traffic should be distributed among nodes of a clustered computer system. The cluster can use the load-balancing policy to balance the service load between several nodes. Note that there can be multiple GIFs on different nodes hosting other shared addresses.

[0013] For scalable services, application instances run on several nodes simultaneously. If the node that hosts the global interface fails, the global interface fails over to another node. If an application instance running fails, the instance attempts to restart on the same node.

[0014] If an application instance cannot be restarted on the same node, and another unused node is configured to run the service, the service fails over to the unused node. Otherwise, it continues to run on the remaining nodes, possibly causing a degradation of service throughput.

[0015] In a conventional highly available system the implementation of resource types, such as failover resource type or scalable resource type, are created manually by a developer for each highly available application. Unfortunately, creating appropriate resource types manually requires significant amounts of time and effort, and therefore, it is time consuming and expensive.

[0016] Accordingly, it would be highly advantageous to have a tool that would automate the process of creation of the aforementioned resource types based on characteristics of a particular clustered computer system and parameters specified by the user. It would also be advantageous to have a tool that would generate utility scripts for starting, stopping and removing an instance of the resultant resource type.

### SUMMARY

[0017] To overcome the limitations described above, and to overcome other limitations that will become apparent upon reading and understanding the present specification, apparatus and methods are disclosed that automatically generate resource types for installation on nodes of the clustered computer system. A tool embodying the disclosed inventive techniques will hereinafter be referred to as the "inventive wizard tool", "inventive wizard", or simply "inventive tool".

[0018] One aspect of the invention is a method for automatic generation of a resource type for an application. Another aspect of the invention is a computer readable medium embodying a program for automatic generation of a resource type for an application. Yet another aspect of the invention is an apparatus configured for automatic generation of a resource type for an application. The generated resource type is installed on one or more nodes of a clustered computer system.

[0019] According to the inventive technique, certain user specified characteristics of the application and the clustered computer system are input using a user interface. Based on the input characteristics, a code for at least one resource type is generated. This code, along with the

application are installed on at least one node of the clustered computer system.

[0020] The application can be a highly available application or a scalable application. The generated resource type can start execution of the application; stop execution of the application; or monitor execution of the application. The code of the resource type generated by the inventive wizard can be a source code. This generated code can be arranged into a software package, such as Unix package, prior to installation on nodes of the clustered computer system. The aforementioned user-specified characteristics can be input using a graphical user interface.

### **DESCRIPTION OF THE DRAWINGS**

[0021] Various embodiments of the inventive wizard tool will now be described in detail by way of example only, and not by way of limitation, with reference to the attached drawings wherein identical or similar elements are designated with like numerals.

[0022] FIG. 1 illustrates an exemplary hardware configuration of a clustered computer system;

[0023] FIG. 2 provides a flow diagram illustrating operation of the inventive resource type wizard;

[0024] FIG. 3 provides an exemplary snapshot of the create screen of the inventive wizard;

[0025] FIG. 4 provides an exemplary snapshot of the configure screen of the inventive wizard.

### **DETAILED DESCRIPTION**

[0026] One or more embodiments of the inventive wizard will now be described in detail with reference to the attached drawings, wherein like numbers represent the same or similar elements. While the following description is in terms of an exemplary mode for achieving one or more objectives of the invention, it will be undoubtedly appreciated by those skilled in the art that many variations may be accomplished in view of those teachings without deviating from the spirit or scope of the described embodiments.

[0027] Fig. 1. illustrates an exemplary hardware configuration of a clustered computer system. In this figure, the clustered computer system comprises nodes 3 and 4 providing services to clients through public network 1, such as the Internet. The system configuration may also include optional second public network 2. In addition to depicted cluster nodes 3 and 4, additional cluster nodes are possible. Disk drives 14 connected to the cluster nodes 3 and 4, using interconnects 15 and 16 respectively, provide local data storage to each of the computer cluster nodes 3 and 4. The nodes 3 and 4 can be additionally interconnected connected through high-speed private networks 7. Multihost disk expansion units 8, 9 and 10 can be used by all the nodes in the cluster to store shared data. These units 8-10 are connected to the computer nodes 3 and 4 using fast interconnects 11-13. The operation of the cluster can be controlled from a administrator's workstation 5, which can access the cluster nodes through the public network 1 and 2 or private network 7.

[0028] The inventive resource type wizard tool automates the creation of resource types to be executed on the nodes of a clustered computer system.

[0029] The inventive tool significantly reduces the time required to develop the highly



available and scalable data services, while simultaneously giving the user the flexibility of fine-tuning the parameters of these services, if necessary. The resultant highly-available applications, running on nodes of a clustered computer system are able to survive the failures of underlying software or hardware, with only a brief interruption of service. On the other hand, the scalable data services generated using the inventive tool are able to increase the performance of the application, by means of executing multiple instances of the application on multiple nodes of the cluster.

*Sub A* [0030] Fig. 2 provides a block diagram illustrating operation of the inventive resource type wizard. Upon the beginning of execution, at block 21, the inventive resource type wizard requests the user to input certain information in block 22, which is used to generate a set of source code files based on the input provided by the user (see block 23). In one embodiment of the invention, the user has the option of having the source code for the resource type generated in C, ksh or perl. C is a programming language well known to persons of skill in the art. Ksh and perl are script programming languages also well known to persons skilled in the art. The aforementioned ksh format is more useful in case the user does not have access to a C compiler or if the user is more comfortable with ksh source code. However, for the ease of extensibility and the richness of underlying functionality, it is preferable to select C as the type of the generated source code. In addition, resource types with ksh source code do not support non-network aware applications or applications with multiple process trees. The inventive wizard tool also generates and customizes the resource type registration (RTR) file. The generated resource code is installed on nodes of the clustered computer system in block 24. The operation of the inventive wizard terminates in block 25.

[0031] In addition to the aforementioned resource types, the inventive wizard generates customized utility scripts for starting, stopping and removing an instance (also known as resource) of the target resource type. The start script takes care of registering the resource type, and creating the necessary resource groups and resources. It also creates the network resources (such as LogicalHostname or SharedAddress) to be used by the application to communicate with the clients over the network. The stop script stops and disables the instance of the resource. The remove script undoes everything done by the start script previously — it stops and removes the resources, resource groups and the target resource type from the system.

[0032] In one embodiment, the inventive wizard packages all generated code into an installable package which can then be installed on all nodes of the computer cluster. In another embodiment of the invention, the code is packaged into a Unix software package. The structure and the manner of implementing a Unix software package is well known in persons of skill in the art.

[0033] In an embodiment of the invention, the resource type wizard supports both network aware as well as non-network aware (or stand-alone) applications. The network aware application is an application that utilizes network in its operation. The non-network aware application does not utilize network connection. Applications of both types are well known to persons skilled in the art.

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[0034] Using the inventive wizard, each type of application can be wrapped either in the aforementioned failover or scalable resource type. The inventive wizard may also support applications having more than one independent process tree that need to be monitored, and restarted, by PMF individually. The manner of creation of such resource types, is described in detail below.

[0035] It is important to note that there are certain prerequisites for an application to be made HA or scalable. Therefore, each application needs to be analyzed individually to decide whether it's capable of being made highly available and/or scalable. This analysis needs to be done by the user before using the inventive wizard.

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[0036] Creation of the resource types using the inventive wizard is a process consisting of one or more of the following two steps, wherein the exact order of the steps or their substeps is not critical to the invention:

- In the first step the user is asked to input some basic information about the resource type to be generated. The input information may include, among other parameters, one or more of the following:
  - the resource type name
  - the vendor id: this would typically be the stock symbol of the vendor or some other identifier that uniquely identifies the vendor. This field is initialized to SUNW (Sun's stock symbol on NASDAQ).
  - installation directory: the user specifies a directory under which the wizard will create a subdirectory formed, for example, by the concatenation of the vendor\_id and the resource\_type\_name. For example, if vendor\_id is SUNW and

resource\_type\_name is "ftp", then the wizard will create a subdirectory SUNWftp under the installation directory specified by the user. SUNWftp will then contain everything that's generated for the target resource type. The wizard also generates a .rtconfig file to keep track of, and to reuse, the user supplied input. The installation directory is initialized to the directory from where the wizard is started.

- failover or scalable: the user chooses whether the target resource type is failover or scalable.
- network aware: the user specifies whether the base application is network aware, i.e. if it uses the network to communicate with its clients.
- C or ksh : the user selects the language in which the source code is to be generated.
- In addition to, or alternatively to the first step, in the second step, the user may be asked to input various configuration parameters for the target resource type. This may include one or more of the following:
  - start command: This the full command line that can be passed to any unix shell to start the application. The complete command line may include all parameters needed to start the application, such as hostnames, port numbers, path to configuration files etc. The completed command line may be placed in quotes.
  - stop command: this optional input specifies the command to be run to stop the base application. If this input is omitted, the generated code uses signals to stop the base application.

- probe command: this optional input specifies a command that can periodically be invoked to do a health check on the application and return appropriate exit status (zero for success and non zero for failure). This command would typically be a simple client of the base application. If this input is omitted, the generated code simply connects and disconnects to the port specified and, if that succeeds, declares the application healthy. The probe command can only be used with network aware applications and is disabled for non-network aware applications.
- timeouts: this field may include the timeouts for the start, stop and probe commands. In an embodiment of the invention these timeouts are initialized to 300, 300 and 30 seconds respectively.

[0037] According to one embodiment of the inventive wizard, there is provided a command line version of the inventive resource type wizard, which incorporates the same two step process with different commands to be run at each step. Specifically, the aforementioned embodiment can be used to create a template for a resource type that uses a Resource Group Manager (RGM) framework to make itself highly available and/or scalable. The aforementioned Resource Group Manager is a software facility used to make cluster resources highly available and scalable by automatically starting and stopping these resources on selected cluster nodes. This embodiment of the inventive wizard tool can be used to create resource type templates for both network-aware as well as non-network-aware applications. Moreover, each kind of application (whether network aware or not) can be made failover or scalable.

[0038] The property of the resource type being failover or scalable is orthogonal to its network-awareness. In other words, each of failover or scalable resources can be either

network-aware or not network-aware. The present embodiment creates a directory of the for each created resource type, for example `<${vendor_id}${resource_type_name}>` under, for example, the `Install_directory`. This directory can contain everything related to the generated source and, subsequently, binary and package files, for the resource type. The present embodiment also creates a `.rtconfig` file to store the user-supplied configuration information for the resource type. Further, the present embodiment lets the user create one resource type per directory and different resource types can be created in different directories.

[0039] The inventive wizard permits the use of certain variables in Start, Stop and Probe command lines whose value will be substituted at runtime (i.e. when run on the cluster). This feature of the invention enables the user to tie these commands to the data which is cluster specific, or configuration dependent. One such example is the hostname (or IP address) on which the application will be listening and serving client requests. It is not possible to determine this value upfront, at the time of creating the resource type through the wizard. However, many applications require the value of hostnames to be specified on the command line.

[0040] This is achieved by specifying these variables on the command line in the `$var_name` format. For example, to start the `echo_server` the hostname may be specified on the command line. This can be done in the following manner:

```
/opt/SUNWscrtw/demo/network_aware/echo_server -p <port_no> -l $hostnames
```

[0041] Note the use of `$hostnames` in the `echo_server` command line. `hostnames` is a Wizard defined variable whose value will be substituted with the LogicalHostname or SharedAddress hostname (essentially an IP address) as configured in the `Network_resources_used` resource property of the resource or this resource type. In case more

than one hostnames are configured in the `Network_resources_used` property, the value of the `hostnames` variable will contain all of them separated by commas (.). If additional parsing is required in such a case, that may be done in a wrapper script.

[0042] The `hostnames` variable is one of the variables supported by the inventive wizard. In another embodiment of the inventive wizard, along with the support for adding new extension properties, as explained in detail below, those properties are also made available in the Start, Stop and Probe command line in the form of wizard defined variables. The aforementioned variables may then be accessed in a similar fashion as `hostnames`, i.e. using `$var_name`.

[0043] Optionally, the aforementioned two step resource type creation process of an embodiment of the inventive wizard may be restartable. In other words, it's possible to quit after filling in information in the step one (and executing it), and then restart the wizard and fill in the rest of the information in step two later. In order to accomplish this, the wizard may be restarted from the same directory where it was run originally. Or, alternatively, the installation directory field can be selected to point to the original directory.

[0044] On startup, the inventive wizard may look for the existence of the `.rtconfig` file and initializes all the fields based on the inputs given previously. Similarly, every time the installation directory is changed, the wizard may look for the existence of the `.rtconfig` file in that directory and initialize as many fields as possible. Optionally, the input fields are left unaffected if the `.rtconfig` file is not found in the new installation directory.

[0045] Leveraging the capabilities described in detail below, it may be possible to reuse the information previously entered for some other resource type to generate a new resource

type. This can be achieved by running the wizard from the same directory where the previous resource type was created. This will result in the wizard reading in all the information from the previous resource type and initializing the input fields with them. The user can then change the installation directory to some other directory and make any modifications to the values read from the .rtconfig file, before generating the new resource type.

[0046] This feature is useful in the following circumstances. Suppose the user starts by prototyping a simple failover application and doesn't yet have a C compiler. Therefore, the user selects ksh as the type of the source code generated for the resource type. However, overtime, the user may find ksh to be the limiting factor in meeting growing needs of the data service. The user may also find that the source code generated in C is more powerful and lets the user access a richer set of APIs. If the user does not want to have to recreate the data service (which the user has previously created in ksh) from scratch in C, the user can follow the procedure described above to clone the data service, this time in C.

[0047] The inventive resource type wizard takes as input a handful of important parameters about the target resource type and generates source code and the resource type registration (RTR) file based on that input. To keep the resource type generation process simple, the input taken by the wizard is not meant to be exhaustive. Therefore, to add more sophisticated features (e.g. validation checks for additional properties), or to tune parameters not exposed by the wizard, one needs to make changes to the generated source code and/or RTR file. The wizard, in addition to generating the source files and the RTR file, also generates the makefile with appropriate targets which can then be used to recompile the source code and regenerate the resource type package. The wizard also gives the user pointers to potential places



where data service specific code might be added. These places are marked in the generated source code by the comments of the form:

```
/** Insert your data service specific code here **/ .
```

[0048] As it has been described in detail above, the inventive wizard creates a "root" directory based, for example, on the vendor\_id and the resource\_type\_name, which is used to house everything related to the target resource type generated.

[0049] The source files generated by the wizard, based on user input, can be, for example, under the src subdirectory under this "root" directory. The binary files generated by compiling these C source files can be under the bin subdirectory of the same root directory. In the case of ksh these files are identical to the ones under the src subdirectory.

[0050] The util subdirectory may contain the utility scripts which can be used to start, stop and remove an instance of the target resource type. The pkg subdirectory is where the final installable package is created. The docs subdirectory may contain customized pseudo text man pages for the three utility scripts. The etc subdirectory contains the RTR file. The RTR file is of the form \${VENDOR\_ID}.\${RT\_NAME}, i.e. if the vendor\_id is SUNW and the resource\_type\_name is ftp, then the RTR file is named SUNW.ftp. Persons of skill in the art will readily appreciate that the aforementioned directory structure is described by way of example only and not by way of limitation.

**[0051]** If the user makes any changes to the source code, the user can recompile the source files using the following command:

`% make`

In the case of ksh source files, this operation reduces to simply copying the updated source files in the bin directory.

**[0052]** After compiling the resource type source code, the package for the resource type can be regenerated using:

`% make pkg`

The older copy of the package in the pkg subdirectory will be overwritten as a result of the previous command.

**[0053]** If the user wants to make changes only to the RTR file, then he only needs to do the second step, i.e. package creation.

**[0054]** Creating resource types for two exemplary applications using the inventive wizard will now be explained in detail.

- Network Aware: A first exemplary application is a simple network aware application that listens on a specified hostname and port number. The following is the usage message from echo\_server:

Usage: echo\_server [-p <port>] [-l <bind address>] [-f <logfile>] [-h]

Arguments:

- l Address to bind to (defaults to none)
- p Port to listen to (defaults to 5000)
- f Logfile to write to (defaults to none)
- h Display usage

A client for the echo\_server is application called echo\_client. The following is the usage message from echo\_client:

Usage: echo\_client -l <address> [-p <port>] [-n <iterations>] [-i <interval>] [-h]

Arguments:

- l Address to connect to
- p Port to connect to  
(defaults to 5000)
- n Number of times to connect to the server  
(defaults to a continuous loop)
- i Time interval in seconds between connections  
(defaults to 0)
- h Display usage

Upon successful connection to the echo\_server, the echo\_client prints out, for example, the date and time and seq\_id of the packet sent, and the (physical) hostname of the server. The latter is useful, for example, to demonstrate the load balancing for scalable applications.

- Non Network Aware: The second application is an exemplary non-network aware

application. It is a simple script, called `print_host`, that prints to a system log file, every 5 seconds, the name of the physical host on which it's running along with the date and time. Because it does not use any network connectivity to perform its job, it's an ideal candidate to demonstrate the capabilities of the inventive wizard relative to the non-network aware applications.

The following may be used as the exemplary commands for creating the resource type for `print_host`:

Start Command	<code>/bin/print_host</code>
Stop Command	Should be left blank. Signals will be used to stop the application.
Probe Command	Being a non-network aware application, it can not have a probe command.

**[0055]** Once the package for the demo resource type has been created, the resultant package should be added to all nodes in the cluster. Then, from any one node in the cluster, the user may run the start utility command, with appropriate arguments, to run the application under the control of the RGM.

**[0056]** A script `preremove` of the exemplary package generated for the target resource type cleans up the cluster by looking for any resources/resource groups that may have been generated, and not removed, by a previous run of the start command. This operation involves running the `scrgadm (1M)` and `scswitch (1M)` commands to offline and remove the resources/resource groups. The first aforementioned command `scrgadm(1M)` manages the

registration of resource types, the creation of resource groups, and the activation of resources within a resource group. This command can also be used to display information on installed resources, resource groups and resource types. The second aforementioned command `scswitch` performs changes affecting node mastering configuration and states for resource groups and disk device groups. Because the aforementioned commands are designed to be run from only one node of the cluster at a time, if the `pkgrm` of the target resource type is attempted from more than one node simultaneously, the inventive `preremove` command will fail on some or all the remaining nodes. This problem can be avoided in a number of different ways:

- By first running the remove script (from one node of the cluster) before attempting the `pkgrm` from any node. The aforementioned `pkgrm` command affects removal of a Unix software package.
- By doing the `pkgrm` first from one node of the cluster, which will take care of all the necessary cleanup, and then doing the `pkgrm` from the remaining nodes, simultaneously.
- If the `pkgrm` does fail, because the user happened to run `pkgrm` simultaneously from more than one node, without having run the remove script first, the user can attempt the `pkgrm` again first from one node, as suggested above, and then from the remaining nodes.

[0057] The inventive resource type wizard can be used to create resource types for applications that have more than one independent process tree. The term "independent process trees" will be used herein with reference to process trees which are monitored and restarted individually. In order to achieve this, each application can be started with its own tag.

[0058] To create the resource type for an application having more than one process tree, the user needs to create a text file. Each line in the aforementioned text file should specify

a command starting different process trees. This text file should then be specified in the "Start Command" text field in the configure screen illustrated in Fig. 3. Furthermore, the user needs to make sure that the text file does not have execute permissions. This enables the wizard to distinguish between a simple executable script containing multiple commands, as opposed to a text file containing commands to start different process trees. Note that if the created text file (having commands to start multiple process trees) does have execute permissions, the resource type (actually its resources) would come up fine with the caveat that all the commands will be started under one process group precluding the possibility of their being monitored and restarted.

[0059] While the invention has been described herein with reference to preferred embodiments thereof, it will be readily understood by persons of skill in the art that numerous modifications in form and detail can be made with respect thereto without departing from the spirit and scope of the invention, as defined in and by the appended claims.

[0060] For example, the user can manually edit the properties contained in the resource type registration file, which were not specified using the configure screen shown in Fig. 3. It is also possible to provide a GUI based tool permitting the users to edit the properties in the resource type registration file and also do sufficient upfront checking to ensure that the values supplied are correct and consistent.

[0061] Persons of skill in the art will also readily appreciate that a GUI based tool can be provided to automate manual adding of new extension properties to the resource type registration file. Finally, it is also possible to generate the source code for the resource type in perl. Perl is a programming script language well known to persons of skill in the art.

[0062] Persons of skill in the art will appreciate that the present invention can be

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